Discovering Soils in the Tropics: Soil Classification in Ghana

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abstract

Early soil surveyors in the tropics encountered unique environmental conditions. Soil survey was challenging in dense tropical vegetation because it was difficult to observe the landscape without clearing survey lines. Cecil Frederick Charter, a British geographer (1905–1956), proposed an interim scheme for the classification of tropical soils on the basis of Neustruev's soil genetic model where soil is a function of climate, vegetation, relief and drainage, parent material, and age. Charter's interim system was hierarchical, with five levels: Order, Suborder, Soil Group Family, Great Soil Group, and Soil Series. Starting in 1937, Charter worked on soil surveys for Trinidad; British Honduras; Antigua and Barbuda, Leeward Islands; and Tanganyika. From 1951 to 1956, Charter directed the Soil Research Institute in Ghana (formerly Gold Coast). He created 37 soil survey regions based on major drainage basins that were mapped using the semi-detailed reconnaissance method (1:250,000). In 1962, Hugh Brammer published soils information related to agriculture and land use in Ghana and summarized Charter's interim system. Correlation of Ghana's soil classification system with the three widely used international systems (FAO, WRB, and U.S. soil taxonomy) is also described. Comparing of national soil maps through time provides insights about the development of soil geography and soil classification concepts for a country. We paper examine three of the eight national maps of Ghana and discuss theoretical developments in the classification of tropical soils in West Africa. Research in soil morphology and genesis is important for soil mapping and classification with applications for land use and management in the tropics.

Early soil surveyors in the tropics encountered unique environmental conditions. Soil survey was challenging in areas of dense tropical vegetation since it was difficult to directly observe the landscape without clearing survey lines. Research and applications of soil morphology, genesis, and classification were important for soil mapping, and for land use and management in the tropics.

Originating in 1946, the soil survey of Ghana (formerly Gold Coast) investigated relationships among soils and various crop diseases, such as swollen shoot associated with cocoa production. The Soil Research Institute (SRI) was a unit of the former West African Cocoa Research Institute, located in the Eastern Region. From 1951 to 1956, Cecil Frederick Charter (1905–1956), a British geographer, directed the SRI with assistance from Hugh Brammer and others (Fig. 1). Charter had previously worked on tropical soil survey in several of the former British colonies. Using Russian scientist S.S. Neustruev's soil genetic model (Neustruev, 1930) in which soil is a function of climate, vegetation, relief and drainage, parent material, and age, Charter and his staff developed their soil series concepts and associated soil landscape models.

This article examines the historical development of a tropical soil classification system by C.F. Charter and illustrates historical linkages

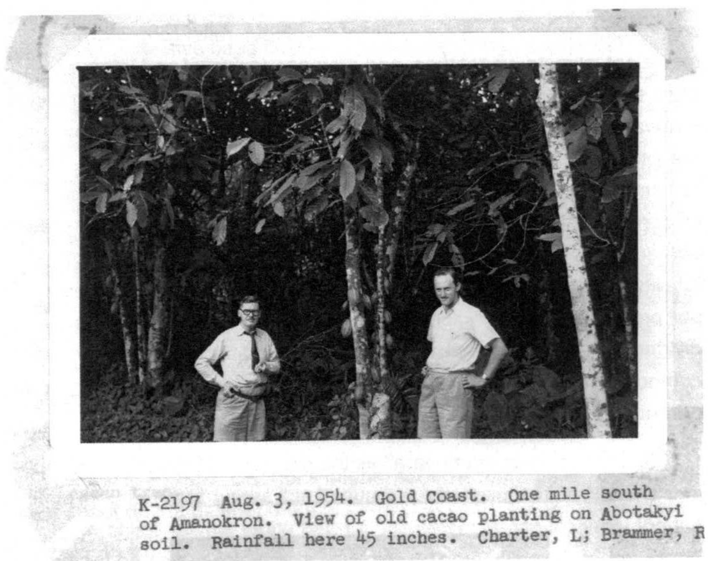

Fig. 1. Cecil F. Charter and Hugh Brammer (source: Kellogg, 1954)

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among Charter, Brammer, Robinson, Kellogg, and others. We also explore some of the philosophical changes in theories of soil formation and soil classification that Charter proposed based on his field experiences in the Caribbean region and Africa. Finally, a comparison of national soil maps through time provides some insights with respect to the development of soil geography and soil classification concepts for a country. This article focuses on three national soil maps of Ghana, which document and help identify developments in the theory of tropical soils classification.

Charter's Work on Tropical Soil Survey and Classification

C.F. Charter was trained by Professor G.W. Robinson in field and laboratory methods at the University College of North Wales. From 1937 to 1951, Charter worked on tropical soil surveys in Trinidad; British Honduras; Antigua and Barbuda, Leeward Islands; and Tanganyika. In 1937, Charter conducted a reconnaissance soil survey of the Antigua and Barbuda Leeward Islands within the British West Indies (Charter, 1937). He collected information and studied the physiography, geology, climate, and vegetation to produce a general soil map for each island. Soil series were described using nine characteristics:

1. texture
2. color
3. calcium carbonate content and distribution within a soil profile
4. occurrence and distribution of manganese oxide concretions
5. occurrence of excess soluble salts
6. "structure of the soil profile" (e.g., profile horizonation)
7. vegetation (both natural and human-affected)
8. occurrence and position of water tables and soil moisture relations
9. "character of the parent material"

The American soil classification system modified by Professor Robinson was used and included soil series and soil types. Soil series were typically subdivided into soil types using the textural class of the surface horizon (e.g., Blubber Valley Sandy Loam). Soil series were grouped into soil suites with five soil suites and 24 soil series identified for Antigua and one soil suite with four soil series mapped in Barbuda. Areas of swamp were not identified as individual soil series.

Charter (1939) worked on a reconnaissance soil survey and the soil classification of Trinidad after receiving a request to conduct a special investigation of soils associated with the sugar-cane estates. The soil forming factors of parent material (geology), relief (physiography, elevation), climate, vegetation, and drainage (external and internal) were studied to classify sugar-cane soils. Soil profiles were examined in excavated pits and using auger borings. Charter classified the soils into the following categories: series, phases, types, suites, and fascs. The soil series consisted of those soils formed under similar environmental conditions with identical parent material and "precisely similar profile characteristics" (Charter, 1939, p. 15). Soil series were named using a locality name and subdivided into types using the texture of the entire soil profile (e.g., Washington Fine Sandy Loam). Charter further subdivided soil types into phases based on minor differences in chemical composition, physical structure, and other conditions, such as depth to parent materials (e.g., shallow phase).

The soil suite concept parallels the modern soil association grouping. The soil suite designated a group of soil series "derived from similar, but not identical parent materials," formed under similar soil forming environmental conditions. The soil suite was typically named for the most important soil series within the group. The soil *fasc* was defined as a group of soil suites developed under similar soil-forming environmental conditions with the exception of parent materials. Environmental conditions such as "seasonal impeded free drainage" were recognized to group soil suites into the fasc. For example in Trinidad, the Waterloo fasc consisted of the Frederick, Washington, Waterloo, Devenish, St. Madeleine, and Hermitage suites and contained 22 named soil series. The report contains numerous hand-drawn diagrams illustrating the "diagrammatic profiles" for each soil phase within a suite. In conjunction with the soil profile descriptions from pit excavations, Charter sampled each soil series for laboratory characterization of mechanical analysis, cation exchange capacity, exchangeable calcium, magnesium and potassium, sulfur, chlorine, organic matter, and pH. In addition to using the laboratory data for soil classification, Charter and P.E. Turner, sugar agronomist, developed an agricultural classification of the sugar-cane soils to help determine recommendations for which sugar-cane varieties were suitable for the various soil groups.

From March to August 1940, Charter conducted a reconnaissance soil survey of British Honduras (Charter, 1941) to determine the suitability for agricultural production on three areas of "Crown land." Survey funding was provided to Dr. Charter in a grant received from the Colonial Development Fund. Charter collected and documented physiographic data and information on topography and stream drainage networks, geology, climate, and vegetation (e.g., forests).

In the British Honduras report, Charter provides a brief overview of his definition of soil and the importance of field observations using a geologic section or weathering profiles. The observed section included the solum and the parent material (either in situ or transported). Charter commented in his report that, for the Tropics, agricultural suitability should not be based on the solum by itself but must include the "crust of weathering." Understanding the weathering profile was important because, according to Charter, the solum, or "true soil", frequently "disappeared completely" or was "diluted beyond recognition" by subsurface materials moving upward from land management practices (i.e., plowing, trenching).

Charter began the discussion of soil classification in this report by emphasizing the economic value of soil survey for transferring agronomic knowledge based on an understanding of soils in one geographic area to another that may be similar in morphology (and presumably similar in behavior or response to land management). This agronomic knowledge transfer function may have helped foster the "soil series concept" since it is based on soil morphology and soil behavior or management. The agronomic technology transfer function has worked well in various regions. We can also speculate that since soil series are typically defined and named based on data from a limited area, local or indigenous soil knowledge may be intricately woven into most, if not all, of the soil series concepts worldwide.

Charter explained his ideas concerning a "comprehensive [soil classification] scheme" for the Caribbean regions that was multi-categorical. He defined soil series as "all soils derived from more or less identical lithological materials, usually of the same geologic age, under identical or closely similar conditions of weathering." Charter's Caribbean system contained the following hierarchically ordered categories (from lowest to highest): soil phases, soil types, soil series, soil suites, soil fascs, soil groups, and soil divisions. Soil phases and types were subdivisions of soil series. Soils in division I and II were separated largely using geology and topography—group I included soils of the flatlands from unconsolidated sediments, and group II consisted of soils in upland and mountainous landscapes with consolidated rock parent materials.

Charter's system was pragmatic with respect to land use and primarily developed to assess agricultural land use potential. He grouped soils so that cultural and manure application requirements could be properly determined based on earlier research conducted at other locations with similar soils. His system was based on three primary factors: composition of the parent materials, soil profile morphology (horizons, color, texture, structure, etc.), and drainage class and other landscape ("site") characteristics. This system also documented soil series concepts using hillslope diagrams and soil profile sketches. This type of information is important for documenting the local catenary soil geographic relationships. It also has potential for developing predictive soil landscape models for pre-mapping. This potential mapping application could be tested in a series of watershed studies where suitable base map data are currently available.

Ghana's Early Soil Survey Period

The soil survey of Ghana originated in 1946 to investigate relationships among soils and various crop diseases, such as swollen shoot associated with cocoa production (Awadzi and Asiamah, 2002). Located in the Eastern Region of Ghana, the Soil Research Institute (SRI) was a unit of the former West African Cocoa Research Institute. From 1951 to 1956, Charter directed the SRI with assistance from Hugh Brammer and others. Charter subdivided Ghana into 37 soil survey regions primarily based on major river drainage basins and mapped using the detailed reconnaissance method published at a map scale of 1:250,000. Three-hundred sixty different soil series were established and their suitability for crop and livestock production documented in a series of technical reports and memoirs accompanied by analog (i.e., hard-copy) maps.

In 1954, Charter described the soil survey work accomplished in Ghana since 1948 at the Goma Soils Conference (Charter, 1954a). Charter indicated a new procedure, the Detailed Preliminary Survey, was developed, and he planned to "cover the whole of the Gold Coast, 91,843 square miles" with a tentative completion date of 1961. The detailed patterns of soil associations were mapped by the methods described previously with the Preliminary Survey using parallel traverse lines spaced at 5 miles (8 km). Soil associations were organized into (i) consociations, (ii) simple soil associations, (iii) compound associations, (iv) complex associations, and (v) soil complexes. General soil maps showing soil associations were published at 1:125,000 and 1:250,000 scales to inventory the soil resources and help with extension and development activities (Charter, 1954a,b). Soil associations were delineated using survey lines oriented approximately at right (90°) angles to drainage lines (Awadzi and Asiamah, 2002). On agricultural research farms and selected individual farms, detailed soil surveys (1:10,000) were conducted and published in more than 200 Technical and Miscellaneous Reports. Detailed soil surveys on agricultural research farms were conducted at scales ranging from 1:2,500 to 1:5,000 and 1:6,250 to 1:7,920 for some sample strips of 160 acres (Charter, 1954a,b). Soil series were further subdivided into "soil sub-series" that are nearly equivalent to the various phases of soil series (depth, stoniness, gravel occurrence, etc.).

Charter's Interim System of Tropical Soil Classification

During 1954, Dr. Charles E. Kellogg, Director, USDA/SCS Division of Soil Survey documented his observations of Charter and Brammer from his 2-wk visit to Ghana (Kellogg, 1954). Kellogg's African Journals, a historical collection at the USDA National Agricultural Library, describe his field visits and personal meetings with Charter discussing tropical soils and other subjects. Kellogg undoubtedly influenced Charter's concepts of tropical soil classification through his "Preliminary Suggestions for the Classification and Nomenclature of Great Soil Groups in Tropical and Equatorial Regions" presentation in the 1948 First Commonwealth Conference on Tropical and Sub-tropical soils (Kellogg, 1949).

At the 1954 fifth ICSS in Leopoldville, Charter "staunchly defended the traditional genetical system of soil classification" against proposed "formula types of classification" (Brammer, 1956). According to Brammer, Charter prepared a brief outline of his proposal for tropical soil classification in a very short amount of time and presented it at a special symposium on soil classification near the end of the Congress. At the fifth ICSS, Charter presented his system which classified *tropical soils* (emphasis added) using "morpho-genetical principles" (Colloquium on Soil Classification, 1954) and also expressed his "exception" to then-current theoretical direction of classifying soils based on "a restricted view of soil characteristics" that did not consider "concepts of pedogenesis and geographic determinism." During the 1954 colloquium, Charter also proposed the development of small-scale continental maps that illustrated the "catena concept" and would convey the value of the catenas with respect to soil classification and cartography.

Charter's interim system used in Ghana for tropical soil classification was a hierarchical design with 5 levels: Order, Suborder, Soil Group Family, Great Soil Group, and Soil Series. Charter's system had four orders based on one or two dominant soil-forming factors. Soil orders were: Climatophytic Earths (formerly "Zonal" based on climate and vegetation); Topoclimatic Earths (determined by relief and climate); Topohydric Earths (based on relief and drainage); and Lithochronic Earths (development related to parent material and/or time). Following the death of Charter in 1956, Brammer published the interim scheme in the Proceedings of the sixth ICSS in Paris (Brammer, 1956).

In 1962, Brammer published additional detailed soils information related to agriculture and land use in Ghana. Brammer summarized Charter's interim system and showed the hierarchical groupings (Fig. 2). For example, the Latosols of C.E. Kellogg were grouped under the order "Climatophytic Earths" and Suborder "Hygropeds" (i.e., high rainfall caused extensive base depletion and weathering), subdivided into Forest Ochrosol, Savanna Ochrosol, and Forest Oxysol. Each of the 42 Great Soil Groups was discussed with specific soil series named to represent each taxonomic concept. The "topographical soil associations" or hillslope diagrams illustrate the landscape position and parent materials for the soils (Fig. 3). Diagrammatic soil profiles sketches were recorded to document soil profile morphology (Fig. 4 and 5). Soil horizons were typically delineated by soil color, textural class, presence of organic matter, and soil reaction (pH). When observed, mottling, coarse fragments, and the occurrence of stone lines and quartz veins were recorded in the diagrams (Fig. 5, of the Wenchi soil series). Brammer also reported Ghana soil series characterization data obtained from laboratory research conducted by SRI in Kumasi.

During the 1950s, Charter's interim scheme appears to have had a direct effect on the development of the USDA soil classification system. C.F. Charter's proposed Great Soil Groups of "Ochrosols–Oxysols," which formed the basis for some of the modern theoretical concepts of soil classification. Buol and Eswaran (2000) briefly note that the terms

Fig. 2. Charter's interim scheme for tropical soil classification (source: Brammer, 1962).

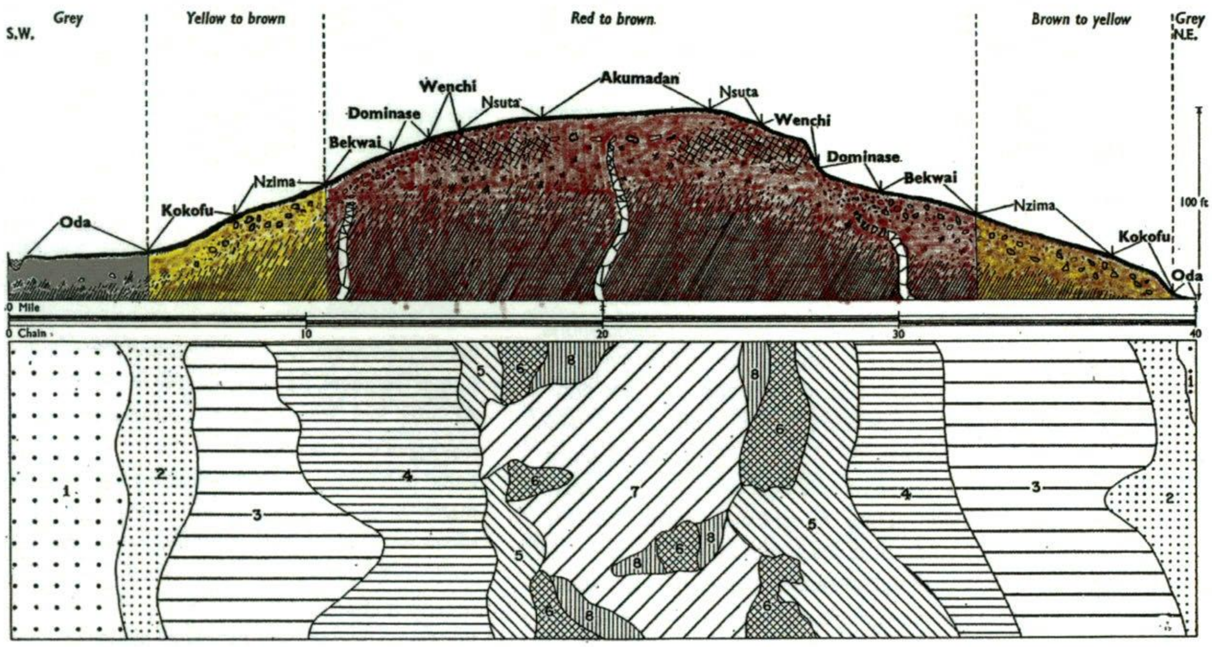
PROVISIONAL CLASSIFICATION OF SOILS SO FAR DISCOVERED IN GHANA[1]

Order	*Suborder*	*(Soil Group Family)*	*Great Soil Group*	*Great Soil Subgroup*
CLIMATOPHYTIC EARTHS	HYGROPEDS	Latosol	Forest Ochrosol	Red Forest Ochrosol Yellow Forest Ochrosol
			Savanna Ochrosol	Red Savanna Ochrosol Yellow Savanna Ochrosol
			Forest Oxysol	Red Forest Oxysol Yellow Forest Oxysol
		?Basisol	Forest Rubrisol	Red Forest Rubrisol Yellow Forest Rubrisol
			Savanna Rubrisol	Red Savanna Rubrisol Yellow Savanna Rubrisol
			Forest Brunosol	
			Savanna Brunosol	
	XEROPEDS		(Reddish Prairie ?)	
TOPOHYDRIC EARTHS	PLANOPEDS	Very Acid Planosol ?	Groundwater Podsol	
		Acid Planosol ?	Groundwater Laterite	
		Calcium Planosol	Tropical Black Earth Tropical Brown Earth	
		Sodium Planosol ?	(Tropical Grey Earth)	
	DEPRESSIOPEDS	Very Acid Gleisol	(Savanna Grey Very Acid Gleisol)	
		Acid Gleisol	(Savanna Black Acid Gleisol) (Savanna Brown Acid Gleisol) (Forest Grey Acid Gleisol) (Savanna Grey Acid Gleisol)	
		Neutral Gleisol	(Forest Black Neutral Gleisol) (Savanna Brown Neutral Gleisol) (Forest Grey Neutral Gleisol) (Savanna Grey Neutral Gleisol)	
		Calcium Vleisol	(Black Vleisol) (Brown Vleisol) (Grey Vleisol)	
		Sodium Vleisol	Solonetz ? Solonchak	
	CUMULOPEDS	Cumulosol	Very Acid Bog ? Acid Bog ? Saline Bog ?	
	HYDROPEDS	Hydrosol	Neutral Hydrosol ? Saline Hydrosol	
LITHOCHRONIC EARTHS	LITHOPEDS	Basimorphic Lithosol	(Black Basimorphic Lithosol) (Brown Basimorphic Lithosol) (Red Basimorphic Lithosol)	(Yellow Basimorphic Lithosol)
		(Non-Basimorphic Lithosol)	(Non-Basimorphic Lithosol)	
	REGOPEDS	Regosol	(Dune-sand Regosol—with calcareous pan) (Dune-sand Regosol—without calcareous pan) (Other Regosols)	
	ALLUVIOPEDS	Alluviosol	(Black Alluviosol) (Brown Alluviosol) (Grey Alluviosol)	

N.B. (i) The use of brackets round a term indicates that the nomenclature is still provisional.
(ii) ? before a term indicates that there is some doubt as to the exact place of the soil group or group family in the classification.
(iii) ? after a term indicates that there is some doubt as to the classification of the soils examined within the group indicated or of the soil group in the group family indicated.

[1] This classification table, together with the account of the major soils of Ghana which follows and the soil map included at the end of the book, are based on information available at the end of 1956.

Fig. 3. Forest Ochrosols soil association over Lower Birrmian phyllite (source: Brammer, 1962; colorized by Thomas Effland).



Topographic section and sketch-map illustrating the distribution of soils within a Forest Ochrosol association over Lower Birrimian phyllite and a peneplain residual, Kumasi residential area (roughly between and parallel to Cedar and Patasi roads).

1. Oda
2. Kokofu
3. Nzima
4. Bekwai
5. Dominase
6. Wenchi
7. Akumadan
8. Nsuta

"Oxysols–*Ochrisols*" [sic] were developed by Charter in 1958. In a 1951 outline of the First Approximation for the revised USDA soil classification system, Dr. Guy Smith proposed the soil order "Oxybods," which is conceptually similar to the 1938 system of "Zonal soils" (Cline, 1979). This term was dropped in the Second Approximation, but the concept of "zonal soils" with A-B-C soils without pans or gleying was retained. The soil order "Oxisols" was developed in 1960 for the Seventh Approximation of the USDA soil classification system.

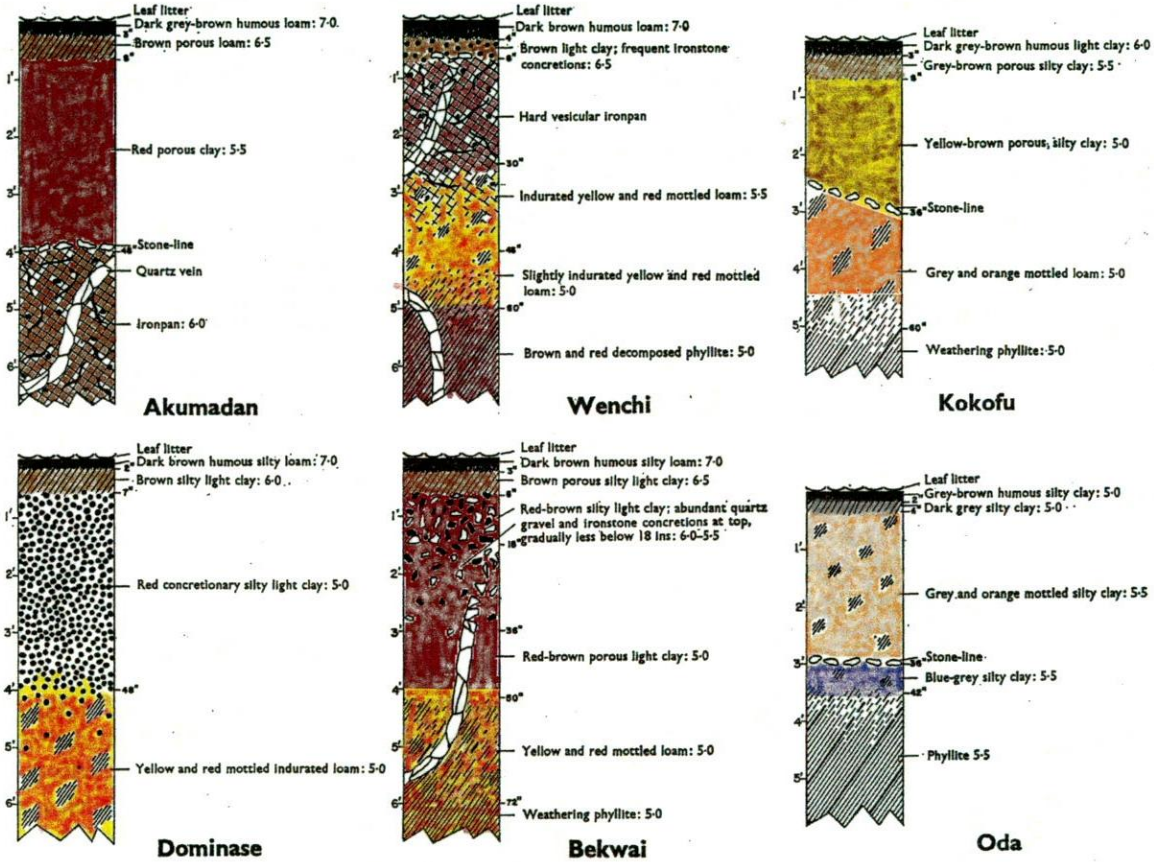


Fig. 4. Soil profiles for the Forest Ochrosols soil association (source: Brammer, 1962; colorized by Thomas Effland).

Soil Series Concepts

The soil series concepts and soil landscape relationships developed by Charter and his staff used the soil genetic model proposed by Neustrev, in which soil is a function of climate, vegetation, relief and drainage, parent material, and age. Soil series concepts were based on descriptions of multiple pedons (~30) for each soil series. Influenced by Milne's work on catenas, soil hillslope models were developed to illustrate surface and subsurface distributions of soil series, parent materials, and vegetation. Soil series were identified at sampling points using idealized hillslope diagrams, soil horizonation, Munsell color, field-determined "Morgan" pH, and a combination of field texture and modified Atterburg ribbon test. Other environmental factors, such as landscape position, parent material, vegetation, and climatic zones, were considered. Soils formed from "drift" materials over residual parent materials and associated with stonelines were frequently observed in roadcuts and other exposures.

Adjei-Gyapong and Asiamah (2001) recently discussed the "gaps and lapses" in the Interim Ghana soil classification system. For example, the total number of soil series (360) may be too large, especially since some soil series occur with limited areal extent. The interim system's emphasis on soil-forming factors with less focus on morphological properties has produced duplicate soil groups. In contrast to other modern soil classification systems (e.g., USDA, FAO, WRB), the interim system does not have diagnostic horizons and uses soil-forming factors and other imprecisely defined characteristics. The terminology of the interim system is not widely studied, and its terms do not clearly convey the accessory properties which are more characteristic of systems such as USDA or FAO.

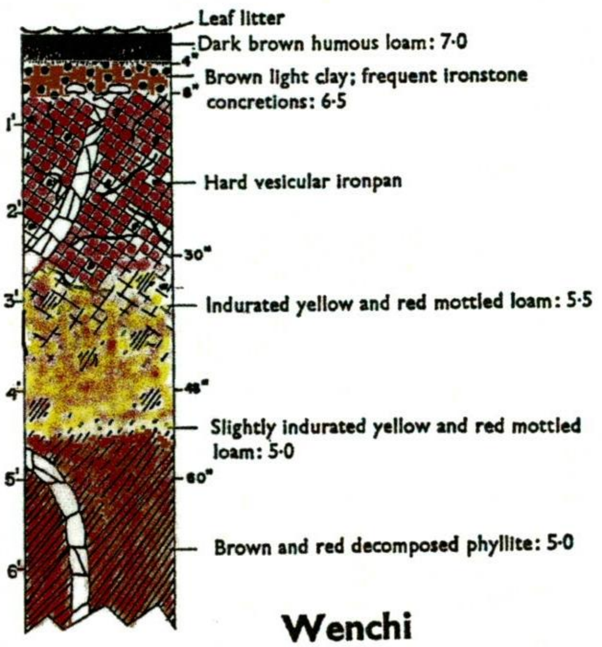


Fig. 5. Wenchi soil profile in a Forest Ochrosols soil association (source: Brammer, 1962; colorized by Thomas Effland).

Soil Correlation

The current soil classification system for Ghana contains 360 soil series. Ghana's soil series include the following Soil Orders from *Soil Taxonomy* (Soil Survey Staff, 1999): Histosols, Entisols, Inceptisols, Alfisols, Ultisols, Oxisols, and Vertisols (Eswaran et al., 1997). The soils of Ghana can be divided into the following 17 FAO Major Soil Groupings: Acrisols, Arenosols, Cambisols, Fluvisols, Ferralsols, Gleysols, Leptosols, Luvisols, Lixisols, Nitisols, Planosols, Plinthosols, Podzolsols, Regosols, Solonchak, Solonetz, and Vertisols (SRI, 1999). The correlation analysis was developed using soil series information in the Appendix of the GERMP report (Boateng et al., 1998). Using the FAO soil classification system (FAO-UNESCO, 1981; SRI, 1999) and a soil correlation matrix modified from Eswaran et al. (1997), the soil series of Ghana were tentatively correlated between the FAO and USDA systems to document the Great Groups in *Soil Taxonomy* (Table 1). Adjei-Gyapong and Asiamah (2002) reported on a soil correlation exercise between the Interim Ghana system and the World Reference Base for Soil Resources. Applying information from Table 4 in Adjei-Gyapong and Asiamah (2002) with some additional research, the soil correlation among the Interim Ghana system, FAO, World Reference Base and USDA *Soil Taxonomy* (1998) could be completed to help improve international communication and increase our understanding of the various soil classification systems. An example of this soil correlation work for selected soil categories is shown in Table 2.

Table 1. Tentative soil correlation of FAO-UNESCO (1981) and USDA Soil Taxonomy (1998) for selected Ghana soils.†

FAO	Series count	USDA Great Group (based on Soil Moisture Regime)			
		Aquic	Udic	Ustic	Aridic
Ferric Acrisols	46	Kandiaquults	Kandiudults	Kandiustults	None
Gleyic Acrisols	3	Endoaquults	None	None	None
Humic Acrisols	10	Umbraquults	Sombrihumults	Paleustults	None
Plinthic Acrisols	2	Plinthaquults	Plinthudults	Plinthustults	None
Haplic Luvisols	19	Endoaqualfs	Hapludalfs	Haplustalfs	Haplargids
Calcic Luvisols	2	Endoaqualfs	Rhodudalfs	Rhodustalfs	Calciargids
Chromic Luvisols	4	Kandiaqualfs	Rhodudalfs	Rhodustalfs	Haplargids
Dystric Plinthosols	2	Plinthaquults	Plinthudults	Plinthustults	None
Eutric Plinthosols	2	Plinthaqualfs	Plinthudalfs	Plinthustalfs	None

† Note: Soil temperature regime is isohyperthermic.

Comparison of National Maps

The comparison of national soil maps through time provides some insights with respect to the development of soil geography and soil classification concepts for a country. In Ghana, national maps with soils information were published as a Geology Map (1947); Great Soil Groups (Provisional; 1958); Great Soil Groups No. 4; C.F. Charter's Preliminary Map of Great Soil Groups (1954); Provisional Map of the Principal Soil Complexes of the Gold Coast; Great Soil Groups (1961); Soil Map of Ghana (1971); and the 1998 Digital Soil Map of Ghana. We examined three maps from 1954 (Fig. 6), 1958 (Fig. 7), and 1998 (Fig. 8).

For Charter's 1954 preliminary map of the Great Soil Groups, color and parent materials were emphasized, with climate and vegetation as the other named soil forming factors (Table 3, Fig. 6). Plant communities varied from Closed Forest to Tree Savannah to Savannah with some Mangrove Swamp and Littoral Forest mainly near the coast. Charter also recognized the influence of "old terrestrial drift" as important to soil formation in various regions of Ghana. In the 1950s, the SRI had employed Helen T. Brash, who specialized in geomorphology. Brash worked with Charter to describe the different geomorphic surfaces in the Gold Coast. She identified two major erosion surfaces in Ghana: a lower one that occurs at 150 to 200 feet elevation near the coast and rises at 6 to 8 feet per mile until 1000 feet elevation at the Voltaian escarpment in the Ashanti region and an older surface that occurs from 1400 to 2500 feet in elevation (Brash, 1962).

The 1958 provisional map of Ghana's Great Soil Groups (Fig. 7) was notably influenced by areas of the major plant communities. The 1958 Ghana map illustrates the Great Soil Groups subdivided by Forest, Interior Savannah, and Coastal Savannah Zones. The Forest Zone contained Forest Oxysols, Ochrosols, Oxysols–Ochrosols intergrades, Rubrisols–Ochrosols intergrades, Regosols, and Litho-

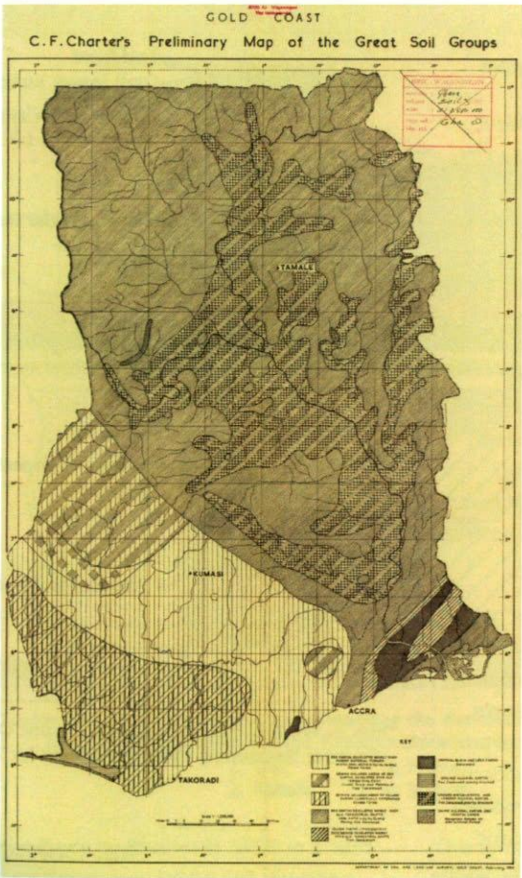


Fig. 6. 1954 (former) Gold Coast C.F. Charter's Preliminary Map of the Great Soil Groups (source Selvaradjou et al. 2005; EuDASM).

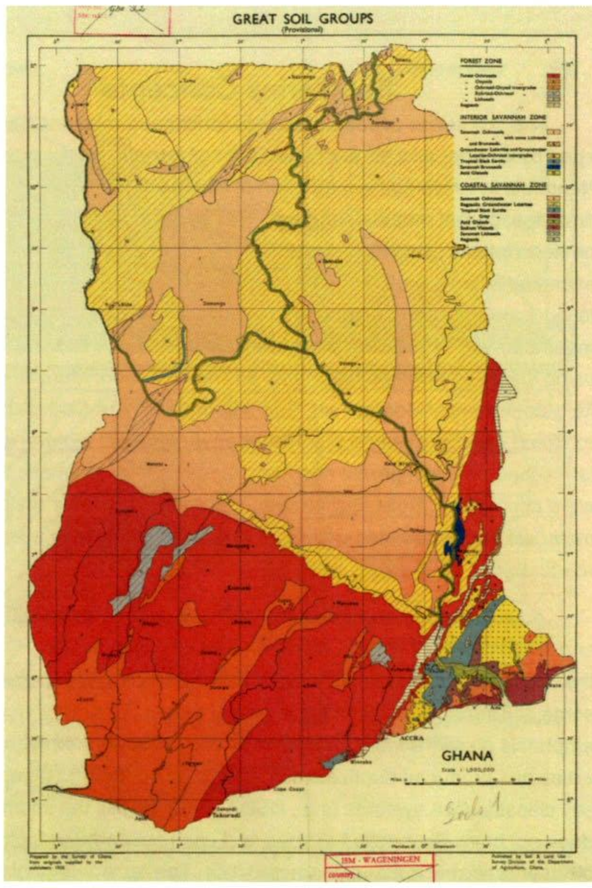


Fig. 7. 1958 Ghana Great Soil Groups (Provisional) (source: EuDASM, 2005).

Table 2. Tentative soil correlation among Charter (1956), FAO (1981), USDA (1998), and WRB (1998) soil classification systems for selected Ghana soils.

Charter 1956 (Brammer, 1962)	FAO 1981 Soil Unit (SRI, 1999)	WRB 1998 (Adjei-Gyapong and Asiamah, 2002)	USDA (1998) Soil Order	USDA Great Group (based on Soil Moisture Regime, SMR)			
				Aquic	Udic	Ustic	Aridic
Forest Oxysols	Ferric Acrisols	Ferralsols/Acrisols	Ultisols/Oxisols	Kandiaquults	Kandiudults	Kandiustults	None
Forest Ochrosols	Gleyic Acrisols	Acrisols/Alisols/Lixisols Nitisols/Ferralsols/Plinthosols		Endoaquults	None	None	None
Savanna Ochrosols	Humic Acrisols	Lixisols/Luvisols/Plinthosols		Umbraquults	Sombrihumults	Paleustults	None
	Plinthic Acrisols			Plinthaquults	Plinthudults	Plinthustults	None
Savanna Ochrosols	Haplic Luvisols	Lixisols/Luvisols/Plinthosols	Alfisols/ Aridisols	Endoaqualfs	Hapludalfs	Haplustalfs	Haplargids
	Calcic Luvisols			Endoaqualfs	Rhodudalfs	Rhodustalfs	Calciargids
	Chromic Luvisols			Kandiaqualfs	Rhodudalfs	Rhodustalfs	Haplargids
Forest Oxysols	Dystric Plinthosols	Ferralsols/Acrisols	Alfisols/ Ultisols	Plinthaquults	Plinthudults	Plinthustults	None
	Eutric Plinthosols			Plinthaqualfs	Plinthudalfs	Plinthustalfs	None

sols. The Interior Savannah displayed Savannah Ochrosols, Lithosols, Brunisols, Groundwater Laterites and intergrades to Ochrosols, Tropical Black Earths, Savannah Brunosols and Acid Gleisols. The Coastal Savannah Zone included Savannah Ochrosols, Regolic Groundwater Laterites, Tropical Black and Gray Earths, Acid Gleisols, Sodium Vleisols, Savannah Lithosols, and Regosols.

The 1999 Digital Soil Map of Ghana (Fig. 8) uses the FAO 1988 Soil Map of the World symbols for the various major soil groupings. Based on the 1999 map, the soils of Ghana include the following FAO Major Soil Groupings: Acrisols, Alisols, Arenosols, Cambisols, Fluvisols, Ferralsols, Gleysols, Leptosols, Luvisols, Lixisols, Nitisols, Planosols, Plinthosols, Regosols, Solonchak, Solonetz, and Vertisols. Although the major plant communities are not displayed on the map, the influence of modern day "agro-ecological zones" is an important factor in soil classification in Ghana because the zones are based, in part, on the major plant communities (SRI, 1999).

Summary

C.F. Charter was one of the pioneers for early soil survey activities in the British Colonies within the tropical regions of Africa and Central America. He was strongly influenced by soil concepts, ideas, and theories of soil formation published by G.W. Robinson, C.F. Marbut, G.W. Milne, C. E. Kellogg, and others. In the 1950s, Charter proposed an interim comprehensive system of soil classification based on his knowledge of the environmental soil forming factors and detailed field observations across wide geographic regions from the Caribbean Islands to British Honduras and Ghana of West Africa. The classification system was hierarchical in design, with five to seven levels, and the detailed categories included modern-day equivalents such as the soil phases, soil types, and soil series. His broader soil categories of soil suites and fascs clearly resemble the soil associations currently used in the United States' and other countries' soil surveys. Charter's proposed Oxysols soil order was later adopted with some modifications by the U.S. soil classification system developed during the 1950s to 1970s and resulting in the USDA's *Soil Taxonomy.*

Following the independence of Ghana in 1957, the Soil Research Institute (SRI) was established in the early 1960s, and soil survey activities resumed according to the scientific-based field methods and soil classification system established by Charter, Brammer, and others.

Table 3. Ghana (former Gold Coast) Great Soil Groups (Charter, 1954a).

Great Soil Group	Pedogenetic factor	Plant community
Red Earths	Parent material (PM) formed in situ	Closed Forest
..and Areas of Red Earths	Old terrestrial drift and in situ PM	Closed Forest and Patches of Tree Savannah
..and Areas of Yellow Earths	Climate effect	Closed Forest
Red Earths	Drift PM influence	Mainly Tree Savannah
Yellow Earths	Lithologic effect on drift	Tree Savannah
Tropical Black and Grey Earths	Parent material	Savannah
Leached Alluvial Earths	Poor drainage	Tree Savannah
Groundwater Laterites and Leached Alluvial Earths	Poor drainage	Tree Savannah
Saline Alluvial Earths and Coastal Sands	Time	Mangrove swamp, Littoral Forest

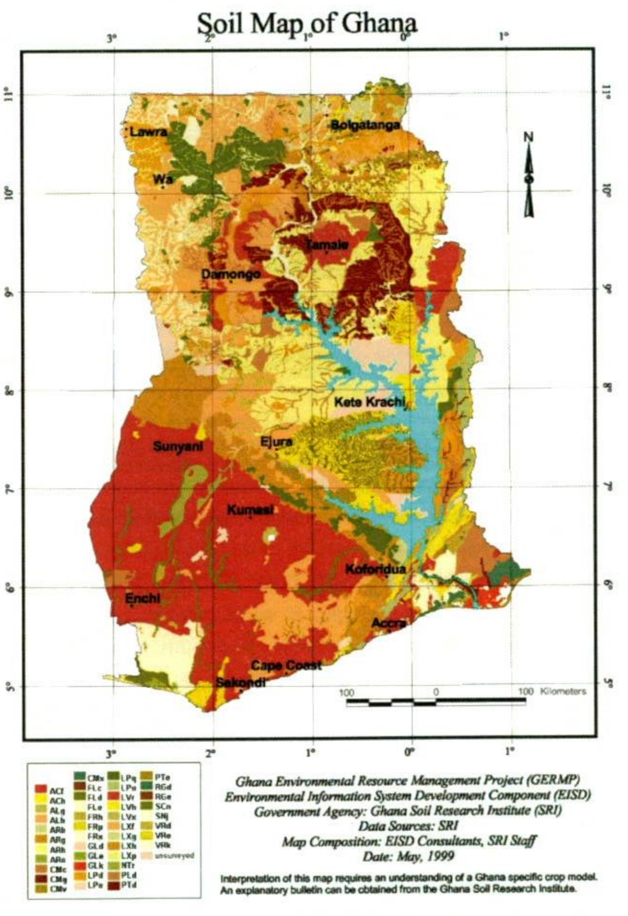


Fig. 8. 1999 Digital soil map of Ghana (source: SRI, 1999).

Since 1960, the SRI has published more than 200 technical and miscellaneous reports on the soils of Ghana based on the 360 soil series that Charter and others documented from soil profile descriptions of multiple pedons or sampling units. It should also be noted that Charter's interim system of tropical soil classification continued with several soil survey staff, such as Dr. Peter Ahn, a British soil scientist, and Dr. S.G. Asamoah and Dr. S.V. Adu, both Ghanaians, who applied Charter's system in soil surveys in the southwestern and northern regions of Ghana, respectively. In addition, two former SRI Directors, Dr. H.B. Obeng and Dr. R.D. Asiamah, continued to use Charter's soil classification system when they were the leaders of Ghana's soil survey work. Efforts to correlate the Ghanaian system of soil classification with international systems such as U.S. Soil Taxonomy, FAO, or the WRB were initiated, but additional research is required to complete the correlation for improved communication among users of soil survey information. Furthermore, the comparison of national soil maps through time provides some insights into the development of soil geography concepts and soil classification theories for a country or region.

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